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OK 9/24/71

AN EVALUATION
OF COMMERCIAL
POLYARYL POLYI-
SOCYANATES IN A
BENDIX KANSAS CITY
FOAM SYSTEM

BDX-613-508

May, 1971

THIS DOCUMENT CONFIRMED AS
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Technical Communications

Bendix

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KANSAS CITY DIVISION
KANSAS CITY, MISSOURI**

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ABSTRACT

Presented in this report are the effects of commercially available polyaryl polyisocyanates on Thermalthane 4003-8, a foam system developed at Bendix Kansas City. The several tests performed on the rigid foam samples employing these compounds indicated Kaiser's NCO-20 to possess the best thermal stability at elevated temperatures.

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SUMMARY

The purpose of this investigation was to determine whether commercially available polyaryl polyisocyanates would be suitable alternates for Upjohn's PAPI, the material currently used by Bendix Kansas City in the Thermalthane 4003-8 foam system.

Analyses of the Upjohn material and four other polyaryl polyisocyanates-- NCO-20 (Kaiser), Mondur MRS (Mobay), WUC-309T (Wyandotte), and NIAX-AFPI (Union Carbide)--involved the following procedures:

- A comparison of the chemical and physical properties of the polyaryl isocyanates as received;
- The synthesis, testing, and comparison of the prepolymers prepared from the isocyanates; and
- The preparation and testing of foam specimens employing the synthesized prepolymers (T-components) and one lot of the Bendix-developed Thermalthane 4003-9 R-component.

Gel permeation chromatography, infrared and elemental analyses were performed on each material for characterization. Tests to determine the compressive strengths of cured foam samples were performed over a temperature range of 80 to 400°F. Thermomechanical analysis (TMA), thermogravimetric analysis (TGA), and differential thermal analysis (DTA) were also employed.

The results of this investigation show that the five polyaryl polyisocyanates meet the requirements of Material Standard 4612092. The prepolymers synthesized from the various polyaryl and foam samples meet the requirements of Material Standard 2170452-8 except for two rise-rate parameters exhibited by the Wyandotte and Kaiser materials. Of the five commercial polyaryl polyisocyanates studied, the data strongly suggest that there are only three sources for these materials. The PAPI (Upjohn) and NIAX-AFPI (Union Carbide) materials appear to be the same, and the NCO-20 (Kaiser) and WUC-309T materials appear to be the same. Mobay's Mondur MRS is different from all the other polyaryl polyisocyanates.

Based on the results of the work described in this report and because Kaiser is a direct source for chemical materials, Kaiser's NCO-20 polyaryl polyisocyanate will be evaluated in the BKC Thermalthane 4003-8 foam system using production processes.

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DISCUSSION

SCOPE AND PURPOSE

Polyaryl polyisocyanate is a generic term used to describe the isocyanates derived from aniline-formaldehyde condensation products. The polyamines used in the preparation of these isocyanates provide a mixture of isomers and compounds of varying molecular weights which yield a product of low freezing point.¹

The purpose of this investigation was to determine whether other commercially available materials would be suitable alternates for the polyaryl polyisocyanate compound currently purchased by Bendix Kansas City from the Upjohn Company. The subject material is employed in the Thermalthane 4003-8 foam system.

PRIOR WORK

There was no work on this project prior to that reported here.

ACTIVITY

The procedure followed in this investigation consisted, essentially, of three parts:

- A comparison of the chemical and physical properties of the isocyanates as received;
- The synthesis, testing, and comparison of the prepolymers prepared from the isocyanates; and
- The preparation and testing of foam specimens employing the synthesized prepolymers (T-components) and one lot of the Bendix-developed Thermalthane 4003-8 R-component.

Materials

The isocyanates used in this investigation consisted of PAPI (Upjohn), NCO-20 (Kaiser), Mondur MRS (Mobay), WUC-309T (Wyandotte), and NIAX-AFPI (Union Carbide). Prepolymers based on each isocyanate were synthesized using the procedure employed to prepare the T-component for the Thermalthane 4003-8 foam system. One lot of trimethylolpropane/ε-caprolactone polyester polyol (Upjohn's CPR Resin 510 or the comparable BKC Resin 1105) was used in the synthesis of each prepolymer. The same lot of Thermalthane

4003-8 R-component was used with each of the isocyanate prepolymers in preparing rigid urethane foams.

Apparatus and Procedure

Prepolymers

The apparatus used to prepare the prepolymers consisted of a 4,000-ml resin flask fitted with a Barrett distilling receiver, stirrer, water-cooled condenser, thermocouple, and dry nitrogen inlet. The prepolymers were prepared by adding the isocyanate to the reaction flask in two parts. The first part was approximately 42 percent of the total weight of the isocyanate; the second, approximately 58 percent of the isocyanate. The amount of isocyanate used was based on a prepolymer having an amine equivalent of 148 (± 3).

The first portion of the isocyanate was placed in the reaction flask and heated to 250°F with the use of a heating mantle. The trimethylpropane/ ϵ -caprolactone polyester polyol was placed in a beaker and heated in an air-circulated oven to 250°F. As soon as both components had reached 250°F, the resin was added to the reaction flask containing the first part of the isocyanate.

The temperature generated by the reaction of the mixed components was allowed to reach 290°F. After the mixture had cooled to 160°F, the second portion of isocyanate was added. The mixture was allowed to cool to 125°F and placed in a glass jar. The contents were then purged with nitrogen, and the jar was sealed.

Foam Blocks

All foam blocks were prepared by mixing the two components (prepolymer and Thermalthane 4003-8 R-component) for 2-1/2 minutes using a Conn-type impeller fitted to a high-speed, air-driven stirrer. Quantities of the material adequate for the desired density were weighed into the two types of molds used to prepare the foam specimens. One of the molds was used to produce 6- by 6- by 1-inch foam blocks; the other, 4- by 6- by 12-inch blocks. The mold preheat ranged from 110°F to 115°F. A fluorocarbon mold release was used to aid in the removal of the cured foam specimens from the molds. The foam blocks were then cured for 8 hours at 325°F. Table 1 gives the formulation of the Thermalthane 4003-8 foam.

Rise-Rate Properties

All rise-rate analyses were made with the Fluidyne Rise-Rate Measuring System, Model 111. This instrument measures the time of initial rise, the average and maximum rates of rise, and the height of foam rise. The foam was prepared by mixing 348.0 gm of prepolymer and 152.0 gm of Thermalthane 4003-8 R-component using a General K 2423 mixer. The material was

Table 1. Formulation for Thermalthane
4003-8 Foam

Material	Weight (g)
R-component	
ε-caprolactone/pentaerythritol polyester polyol (OH No. 605)	100.0
Water	2.8
R-150 (cell stabilizer)	4.5
Quadrol	0.8
N-methylmorpholine	0.2
T-component	
Polymeric isocyanate- ε-caprolactone/trimethylolpropane prepolymer (Amine equivalent 148 ± 3)	248.4

stirred for 2-1/2 minutes at 1500 rpm using a 2-inch Conn blade. The table rotated at a speed of 5 rpm. The rate on the rise-rate machine was set at 5 inches/minute and the rise height was set at 10 inches. The mixed material (300.0 g) was placed into a 1/2-gallon paper container, and the plumb from the rise-rate machine was positioned in the center of the mixture.^{2,3}

Compressive Strength at 10-Percent Deflection

The compressive strength test was conducted in accordance with ASTM D-695 over a temperature range of 80 to 400°F. The test samples consisted of cylinders 1.129 inches in diameter and 1 inch long machined from the 6- by 6- by 1-inch molded foam blocks. Before the samples were tested, they were conditioned for 1 hour at the test temperature and compressed perpendicular to the direction of foam rise. A loading rate of 0.050 inch/minute was used for the thirty determinations made at the test temperatures. The core samples were 1-inch cubes machined from foam blocks made in the 4- by 6- by 12-inch mold. These were tested both parallel and perpendicular to the direction of foam rise.

Thermogravimetric Analysis (TGA)

All TGA analyses were made with a DuPont Thermogravimetric Analyzer, Model 950. The material samples used in the analyses were from a section of foam blocks. The samples were powdered, placed in a platinum pan,

and weighed. The test was performed in a dry nitrogen atmosphere employing the following parameters for each sample:

Sample weight, approximately 10.77 mg;

Temperature range, 40 to 950°C; and

Heating rate, 10°C/minute.

Differential Thermal Analysis (DTA)

The DTA curves were determined using a DuPont Model 900 Differential Thermal Analyzer operating at the following parameters.

Heating rate	20°C/minute
Heating range	20 to 500°C
ΔT sensitivity	1.0°C/inch
Reference material	Glass beads
Dynamic atmosphere	Nitrogen
Gas flow rate	1 liter/minute
Sample size	5 mg powdered foam

Thermomechanical Analysis (TMA)

The softening points of all samples were determined using a DuPont Model 940 Thermomechanical Analyzer. The quartz probe used with this apparatus was coupled to a movable core differential transformer to sense displacement changes as small as 10^{-5} inches. A penetration probe with a small, flat-tipped projection (0.025-inch diameter) was used at a loading of 5 grams to determine softening points. The samples prepared from the foam blocks were 0.25 inch in diameter and 0.039 inch thick. The heating range for the test was from 25 to 500°C at a rate of 20°C/minute.

Test Results

Summarized in Table 2 are the comparisons that were made of the solids content, ash content, chlorine content, and amine equivalent for the polyaryl polyisocyanates investigated in this project. As shown by the table, all of the materials meet the requirements as designated in Material Specification 461202. Two compounds known to be present in polyaryl polyisocyanates are given in Figure 1. Higher homologs, dimers, and trimers are also present in the polyaryl polyisocyanates.

Table 2. Comparison of the Chemical and Physical Properties of Five Commercial Polyaryl Polyisocyanates

Isocyanates	Amine Equivalent (grams/ equivalent)	Solids Content (Percent)	Total Chlorine (Percent)	Hydralyzable Chlorine (Percent)	Free Chlorine as HCl (Percent)	Ash Content* (ppm)	Viscosity at $77 \pm 2^\circ\text{F}$ (cps)
PAPI (Upjohn)	132.7	0.06	0.73	0.24	0.21	60	251
NIAX-AFPI (Union Carbide)	132.6	0.08	0.71	0.22	0.20	50	272
NCO-20 (Kaiser)	130.8	None	0.38	0.18	0.08	90	230
WUC-309T (Wyandotte)	130.8	None	0.40	0.18	0.09	70	239
Mondur MRS (Mobay)	132.7	None	0.44	0.32	0.11	40	248
Requirements of MS 4612092	134 ± 5	--**	1.5 (max)	--**	0.3 (max)	--**	350 ± 150

* The ashing content was obtained by a slow degradation and volatilization procedure performed on a hot plate employing a 40 to 60 gram sample, followed by a muffle furnace ignition at 700°C . The values represent a minimum number and may be in error by as much as 50 to 100 percent. The analysis of the ash by emission spectroscopy showed the major components in these very small amounts of ash to be iron, zinc, and chromium. The Mondur MRS material appeared to be the cleanest of the five samples from a heavy metals standpoint.

** No requirement in MS 4612092.

Figure 1. Typical Composition of Polyaryl Polyisocyanates and Higher Homologs

The gel permeation chromatographic (GPC) separation of the NCO-20 (Kaiser Chemical Corporation), WUC-309T (Wyandotte Chemical Corporation), NIAx-AFPI (Union Carbide Corporation), and Mondur MRS (Mobay Chemical Company) materials was performed in a manner identical to that performed on previous lots of PAPI (Upjohn), and the data was treated similarly. The GPC peak height ratios for the five compounds are presented in Table 3.

The GPC revealed similarities between the WUC-309T and NCO-20 materials and between PAPI and NIAx-AFPI materials. The Mondur MRS material is somewhat different from the other four polyaryl polyisocyanates as a result of its higher content of ortho, para isomer of methylenebisphenylisocyanate.

The results of the GPC analyses and the test results given earlier in Table 2 indicate that there are only three sources for the polyaryl polyisocyanates: the Upjohn Company, the Kaiser Chemical Company, and the Mobay Chemical Company. Union Carbide's NIAx-AFPI appears to be identical to the Upjohn material; Wyandotte's WUC-309T appears to be identical to the Kaiser material; and the Mobay material is different from the others. Since Upjohn and Kaiser are known manufacturers of polyisocyanate, it would appear that Upjohn is the supplier for Union Carbide and Kaiser is the supplier for Wyandotte.

In addition to the GPC analyses, gas chromatography was employed to measure the isomer content of the lower oligomers. These were the ortho, ortho', ortho, para', and para, para' isomers of methylenebisphenylisocyanate, the major component of the polyisocyanates. Based on the results obtained from three different samples (PAPI, Lot 7130; Kaiser NCO-120; and Mobay MRS), gas chromatography appears to be a pertinent method of testing the polyisocyanates. Several peaks in the chromatogram attributed to the three isomers

Table 3. Gel Permeation Chromatography Analysis (Peak Height Ratio) of Five Commercial Polyaryl Polyisocyanates*

Isocyanates	Peak Heights (mm)					
	A/D	B/D	C/D	D/D	E/D	F/D
PAPI (Upjohn)	10.69	4.13	1.80	1.00	1.17	1.03
NIAX-AFPI (Union Carbide)	8.94	3.70	1.71	1.00	1.05	0.80
NCO-20 (Kaiser)	6.58	2.93	1.54	1.00	0.82	0.50
WUC-309T (Wyandotte)	6.62	3.03	1.59	1.00	0.80	0.48
Mondur MRS (Mobay)	7.13	3.33	1.64	1.00	1.06	0.58
<p>* The six distinct peaks occurring in the gel permeation chromatogram of polyaryl polyisocyanates are designated as A, B, C, D, E, and F. It is believed that Peak A is caused by methylenebisphenylisocyanate, which represents the lowest molecular weight material. Peak F represents a higher molecular weight material. One method of comparing the molecular weight distribution of polyaryl isocyanates is to determine the ratio of the various peak heights to a reference peak, arbitrarily chosen as Peak D.</p>						

provided the results summarized in Table 4. The identity of the first peak is not known at this time.

Table 4. Gas Chromatography of the Isomers of Methylenebis-phenylisocyanate in Three Polyaryl Polyisocyanates

Isocyanate	Peaks (Heights in mm at 1X Sensitivity)				
	1	2 (o, o')	3 (o, p')	4 (p, p')	3/4
PAPI, Lot 7130 (Upjohn)	0	Trace	100	10,400	0.01
NCO-20 (Kaiser)	Trace	5	384	13,800	0.03
Mondur MRS (Mobay)	Trace	16	670	12,900	0.05

Synthesis of Prepolymers

Prepolymers based on each isocyanate were synthesized using one lot of trimethylolpropane/ ϵ -caprolacton polyester polyol (Upjohn's CPR Resin 510 or the comparable BKC Resin 1105). The viscosities of all the prepolymers were held at 4,500 ($\pm$ 750) centipoises at 77°F ($\pm$ 2°). The amine equivalent of each prepolymer was 148 ($\pm$ 3) grams/equivalent. The amine equivalents and viscosities of the polyaryl polymers used in this study are given in Table 5. The results in Table 5 show that all prepolymers synthesized from the polyaryl polyisocyanates meet the requirements of Material Standard 2170562-8.

Table 5. Amine Equivalents and Viscosities of Commercial Polyaryl Polyisocyanate Prepolymers*

Isocyanate Used in Prepolymer	Amine Equivalent (gms/equivalent)	Viscosity (centipoises at 77 $\pm$ 2°F)
PAPI (Upjohn)	149.4	4,300
NCO-20 (Kaiser)	151.0	4,600
Mondur MRS (Mobay)	150.5	4,200
WUC-309T (Wyandotte)	147.3	4,320
NIAX-AFPI (Union Carbide)	148.8	4,850
*MS 2170562-8 Requirement	148 ($\pm$ 3)	4,500 ($\pm$ 750)

Compressive Strength

Table 6 shows the compressive strength and modulus data derived from an average of thirty rigid foam samples (1.129-inch diameter, 1-inch height) for each test temperature. The samples were machined from 6- by 6- by 1-inch foam blocks and tested perpendicular to the direction of foam rise. The data were averaged and normalized to a density of 20 pounds per cubic foot by an IBM 360 computer. As the table shows, all the foam samples had about the same compressive strength at room temperature.

At 400°F, foam samples containing the Mobay material showed the lowest compressive strength (84.0 psi). This could be the result of the higher content of ortho, para' isomer. At the same temperature, the Kaiser material had the highest compressive strength (152.2 psi).

The curves in Figure 2 show the compressive strength versus temperature of rigid foam samples containing polyaryl polyisocyanates from Upjohn, Kaiser, and Mobay.

Table 7 shows the compressive strength and modulus of core samples machined from a molded foam block 4 by 6 by 12 inches. These foam blocks contained three of the commercial polyaryl polyisocyanates: PAPI (Upjohn), NAIX-AFPI (Kaiser), and Mondur MRS (Mobay). The data was derived from an average of 12 rigid foam samples for each test temperature. The compressive strength and modulus data were averaged and normalized to a density of 20 pounds per cubic foot by an IBM 360 computer.

The foam samples containing the Mobay material showed the highest compressive strength at room temperature and the lowest compressive strength at 400°F when tested both parallel and perpendicular to the direction of foam rise. The foam samples containing the Kaiser material showed the highest compressive strength when tested parallel to the direction of foam rise at 275°F. Foam samples employing Mondur MRS (Mobay) and PAPI (Upjohn) showed approximately the same compressive strength at 275°F when tested in the parallel direction. The foam samples containing NCO-20 (Kaiser) polyaryl polyisocyanate showed the highest compressive strength at 400°F when tested in the parallel direction. When the foam samples were tested perpendicular to the direction of foam rise, the samples containing the NCO-20 (Kaiser) polyaryl polyisocyanate showed the highest compressive strength at 275°F and 400°F.

The compressive strengths of rigid foam samples containing the different polyaryl polyisocyanates studied in this project meet the requirements of Material Standard 2170562-8. However, foam using Mobay's Mondur MRS exhibits a significantly lower compressive strength at 400°F indicating that undesirable thermal properties may be associated with this material.

Text continued on page 27.

Table 6. Average Compressive Strength and Modulus of Rigid Foam Based on One Lot of BKC Thermalthane 4003-8 R-Component and Different Commercial Polyaryl Polyisocyanate Prepolymers

Isocyanate Employed in Prepolymer	Test Temperatures							
	Room Temperature		275°F		325°F		400°F	
	Compressive Strength (psi)	Modulus (psi)	Compressive Strength (psi)	Modulus (psi)	Compressive Strength (psi)	Modulus (psi)	Compressive Strength (psi)	Modulus (psi)
PAPI (Upjohn)	653.5	18,779	348.9	10,766	253.1	8,104	116.2	2,354
Standard Dev.	34.5	4,187	29.2	2,919	15.1	930	14.9	178
NIAX-AFPI (Union Carbide)	672.9	21,711	368.2	13,316	298.3	8,994	146.7	3,453
Standard Dev.	37.2	2,255	35.0	818	9.3	596	7.5	401
WUC-309T (Wyandotte)	732.9	26,643	360.1	16,125	268.2	10,380	118.2	2,324
Standard Dev.	76.0	2,706	30.0	1,750	22.0	973	12.0	333
NCO-20 (Kaiser)	689.8	23,964	343.2	13,614	285.2	10,927	152.2	3,893
Standard Dev.	58.7	2,424	36.6	1,194	20.7	949	8.5	485
Mondur MRS (Mobay)	702.5	24,156	344.7	12,507	261.0	8,113	84.0	1,546
Standard Dev.	43.0	2,976	16.0	1,577	16.2	802	6.0	165
Requirement of MS2170562-8	550 (minimum)	--*	250 (minimum)	--*	--*	--*	--*	--*

Note: The compressive strengths were normalized to a density of 20 lb/ft³. The data was derived from 30 samples for each temperature. Test samples were machined from 6- by 6- by 1-inch foam blocks.

* No requirement in MS 2170562-8.

Figure 2. Effects of Temperature on Compressive Strengths of Rigid Foam Samples Containing Prepolymers of Three Commercial Polyaryl Polyisocyanates

Rise Rates

Table 8 shows the rise-rate parameters of foam containing different commercial polyaryl polyisocyanate prepolymers. The foam samples containing NCO-20 (Kaiser) and WUC-309T (Wyandotte) had the highest rise-rates with similar results for the two materials. Foam samples containing the NIAX-AFPI (Union Carbide) and PAPI (Upjohn) prepolymers showed the lowest rise rates with the results being similar. Since the foam samples containing the Mondur MRS (Mobay) prepolymer were different from all the other materials, it would again appear that there are actually only three sources for the five polyaryl polyisocyanates studied.

The rise-rate results (Table 8) show that PAPI (Upjohn), AFPI (Union Carbide), and Mondur MRS (Mobay) meet the requirements of Material Standard 2176562-8. The foam samples containing the WUC-309T (Wyandotte) and NCO-20 (Kaiser) materials were not within the limits specified for two of the rise-rate parameters (maximum velocity and rise-rate constant).

Thermal Analysis of Rigid Foam

The stability of urethane varies greatly depending on its structure. Urethanes from tertiary alcohols may decompose readily at temperatures as low as 50°C while urethanes from many primary and secondary alcohols may undergo changes slowly at 150 to 200°C. The environment (the presence of other reactants and catalysts) also greatly influences the stability of the urethanes.

Studies of the thermal decomposition of substituted urethanes have shown that three general types of reactions may take place.^{4, 5, 6}

1. Dissociation to isocyanate and alcohol.

2. Formation of primary amine and olefin.

3. Formation of secondary amine.

Engel and co-workers studied the thermal decomposition of a variety of crosslinked polyurethanes prepared from polyesters and MDI (methylenediphenylisocyanate).⁷ They found that decomposition in air and in an inert medium were essentially the same, indicating that oxidation did not play a role in the initial decomposition. In addition, changes in crosslinking had

no effect on the rate as long as the ester-urethane group ratio remained constant; otherwise, increases in crosslinking improved the thermal stability. These results support the belief that urethane dissociation is the primary reaction involved in initial decomposition of such polymers.

Since urethanes containing no hydrogen on the nitrogen atom cannot dissociate to the isocyanate and hydroxyl precursors, polymers of this type should show improved thermal stability. This premise has been verified by Dyer and Hammond.⁸ Studies in the range of 230 to 285°C showed that polymers from aliphatic di-secondary amines and aliphatic bischloroformates were more stable than those from 4,4'-diaminodiphenylmethane derivatives. Blachell and Ngoc Son also found greatly improved color stability at 150°C when the urethane nitrogen atoms in a polyurethane were fully alkylated.⁹

The TGA curves of the foam samples containing three of the five polyaryl polyisocyanates examined are shown in Figure 3. Although the curves are somewhat similar, the samples containing NCO-20 (Kaiser) showed a higher percent residue at 600°C than did the foam samples containing PAPI (Upjohn) and Mondur MRS (Mobay). The foam samples containing the Mobay material showed the lowest percent of residue at 600°C.

Typical DTA profiles of foam samples containing some of the commercial polyaryl polyisocyanates are shown in Figure 4. Since DTA detects essentially all thermal changes in a material as the temperature is raised, the curves are somewhat complicated for materials as complex as rigid urethane foams. Such curves reflect both first and second order transitions. In Figure 4 the curves show chemical reactions between unreacted functional groups, melting, and volatilization. In spite of the complexity of the urethane foams, some general features are indicated by their curves.

The three curves are similar in character, indicating that the decomposition mechanisms of the three samples were similar. All samples of rigid foam showed an endothermic degradation at approximately 300°C. Such degradation is also indicated in the TGA curves of Figure 3 by the rapid loss of weight which occurs within the same temperature range. The broader shape at about 375°C on the DTA curves indicates a different decomposition mechanism, as is also indicated in the TGA curves of Figure 3.

The TMA curves are shown in Figure 5. These show the softening points of rigid foams containing different polyaryl polyisocyanates. As shown in the figure, all foam samples exhibited similar softening points at approximately 200°C.

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Figure 3. TGA Curves of Foam Samples Containing Three Commercial Polyaryl Polyisocyanates

Figure 4. DTA Curves of Foam Samples Containing Three Commercial Polyaryl Polyisocyanates

Figure 5. Softening Point Curves of Foam Samples Containing Three Commercial Polyaryl Polyisocyanates

ACCOMPLISHMENTS

The results obtained in this investigation provide the bases for the following conclusions.

- The five polyaryl polyisocyanates studied meet the requirements of Material Standard 4612092. The prepolymers synthesized from the various polyaryl polyisocyanates and foam samples meet the requirements of Material Standard 2170562-8 with the exception of two rise-rate parameters exhibited by WUC-309T (Wyandotte) and NCO-20 (Kaiser).
- Of the five commercial polyaryl polyisocyanates studied, the data strongly suggest that there are only three manufacturers of polyisocyanates. The PAPI (Upjohn) material appears to be the same as NIAx-AFPI (Union Carbide), and the NCO-20 (Kaiser) material appears to be the same as WUC-309T (Wyandotte). Mondur MRS (Mobay) is different from all of the other four isocyanates.
- The foam samples machined from the 6- by 6- by 1-inch foam blocks and containing NCO-20 (Kaiser) showed the highest compressive strengths at 400°F while foam samples containing Mondur MRS (Mobay) showed the lowest compressive strengths. At 275°F, all samples showed similar compressive strengths.
- Rigid foam core samples machined from 4- by 6- by 12-inch foam blocks and containing Mondur MRS (Mobay) showed the highest compressive strength at room temperature (80°F) and the lowest compressive strength at 400°F when tested both parallel and perpendicular to the direction of foam rise.
- The foam samples containing NCO-20 (Kaiser) and WUC-309T (Wyandotte) polyaryl polyisocyanates showed the highest rise rates (reactivity), while the foams containing PAPI (Upjohn) and NIAx-AFPI (Union Carbide) showed the lowest rise rates. The rise rate of the Mobay material was between the top and low values obtained for the four other materials. The thermal decomposition properties for each of the foams containing the five polyaryl polyisocyanates were similar.

FUTURE WORK

Based on the results of the work described in this report and because Kaiser is a direct source for chemical materials, Kaiser's NCO-20 polyaryl polyisocyanate will be evaluated in the BKC Thermalthane 4003-8 foam system using production processes.

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